US009356274B2

(12) **United States Patent**
Jo et al.

(10) **Patent No.: US 9,356,274 B2**

(45) **Date of Patent: May 31, 2016**

(54) **ELECTRODE ASSEMBLY AND RECHARGEABLE BATTERY USING THE SAME**

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(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 1351 days.

(21) Appl. No.: **13/064,242**

(22) Filed: **Mar. 14, 2011**

(65) **Prior Publication Data**

US 2011/0244284 A1 Oct. 6, 2011

(30) **Foreign Application Priority Data**

Apr. 1, 2010 (KR) 10-2010-0030072

(51) **Int. Cl.**

H01M 10/36	(2010.01)
H01M 2/16	(2006.01)
H01M 10/04	(2006.01)
H01M 10/052	(2010.01)
H01M 10/0587	(2010.01)
H01M 10/42	(2006.01)

(52) **U.S. Cl.**

CPC ***H01M 2/1686*** (2013.01); ***H01M 10/0431*** (2013.01); *H01M 10/052* (2013.01); *H01M 10/0587* (2013.01); *H01M 10/4235* (2013.01); *Y02T 10/7011* (2013.01)

(58) **Field of Classification Search**

None

See application file for complete search history.

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(57) **ABSTRACT**

An electrode assembly includes a positive electrode including a positive electrode current collector and a positive electrode active material layer on the positive electrode current collector, a negative electrode including a negative electrode current collector and a negative electrode active material layer on the negative electrode current collector, and a separator between the positive and negative electrodes, the separator including a heat-resistive unit and a lubrication unit, the heat-resistive unit having a heat-resistive material, and the lubrication unit being at an inner front end of the spirally winding separator and having a friction coefficient that is lower than that of the heat-resistive unit.

19 Claims, 10 Drawing Sheets

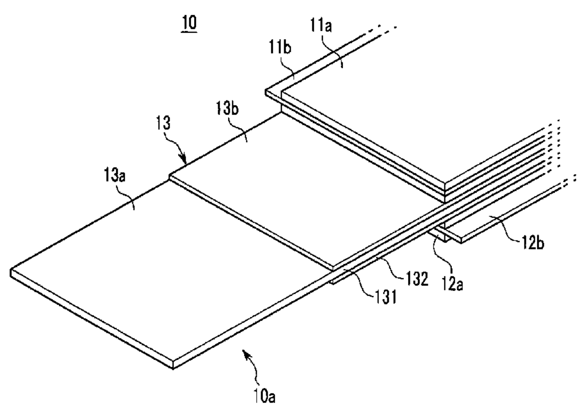


FIG. 1

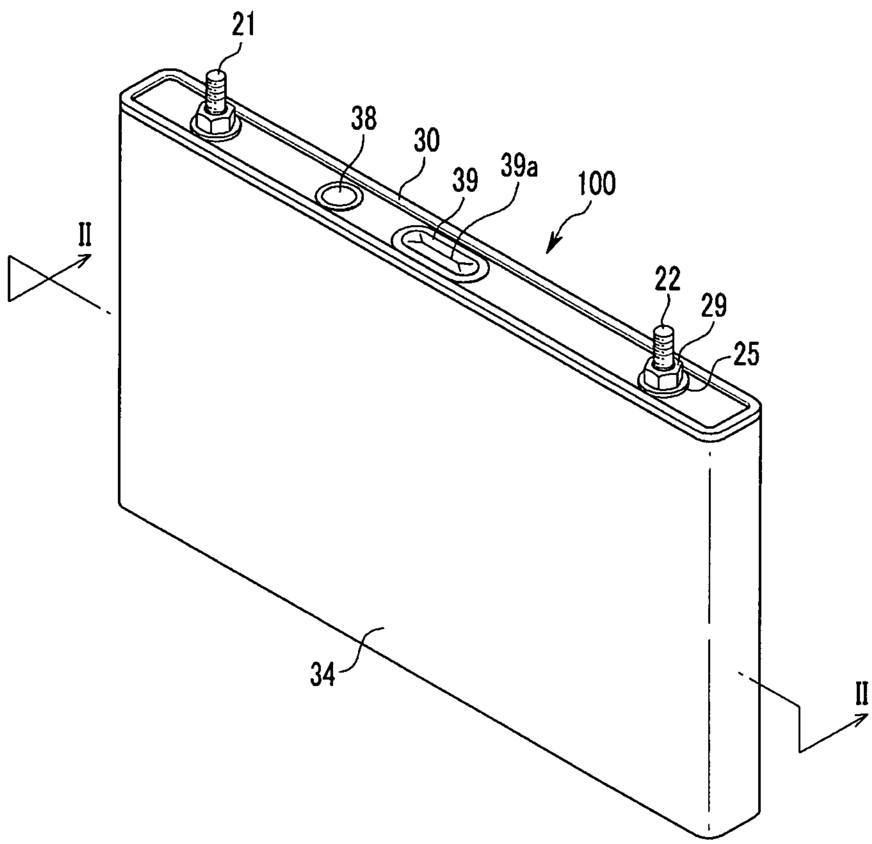
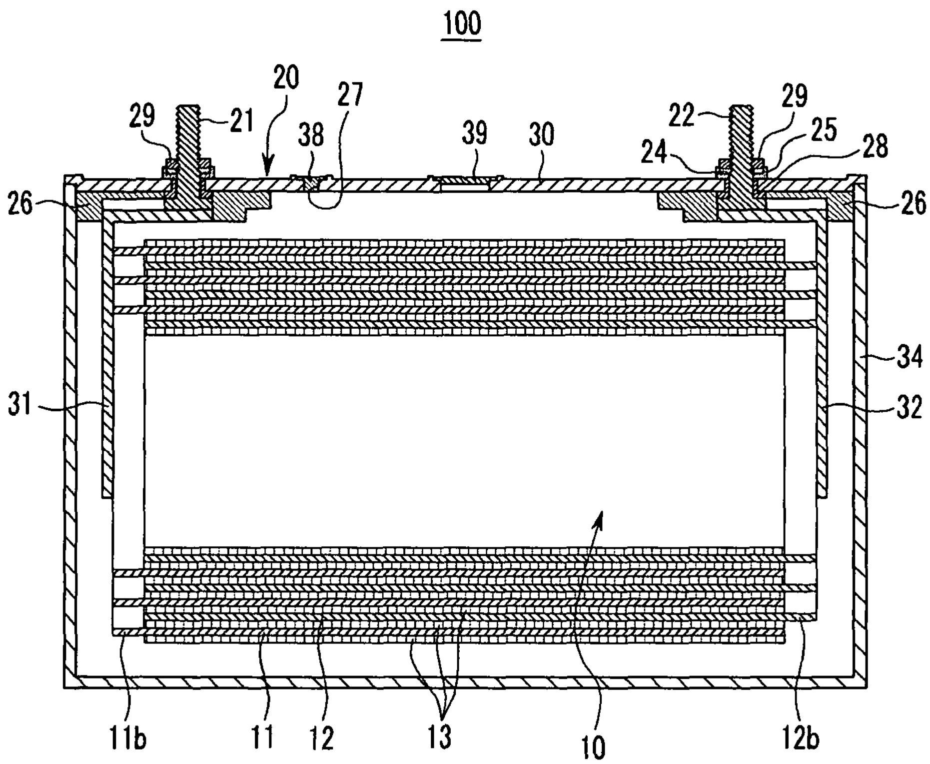


FIG. 2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11b
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12b

FIG. 3

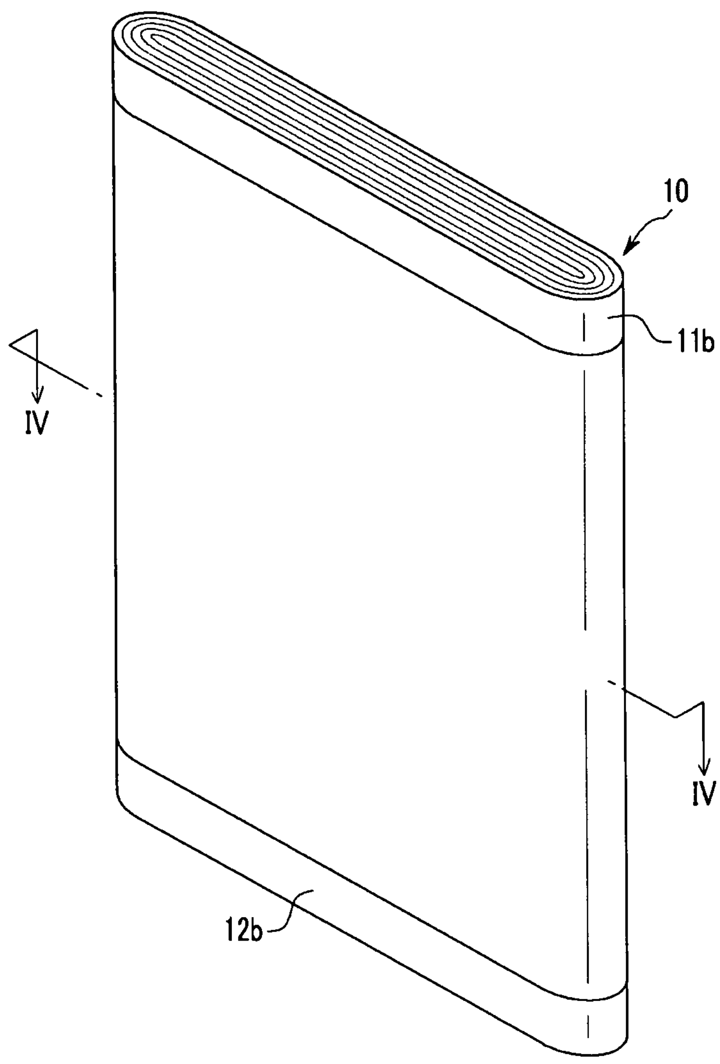


FIG. 4

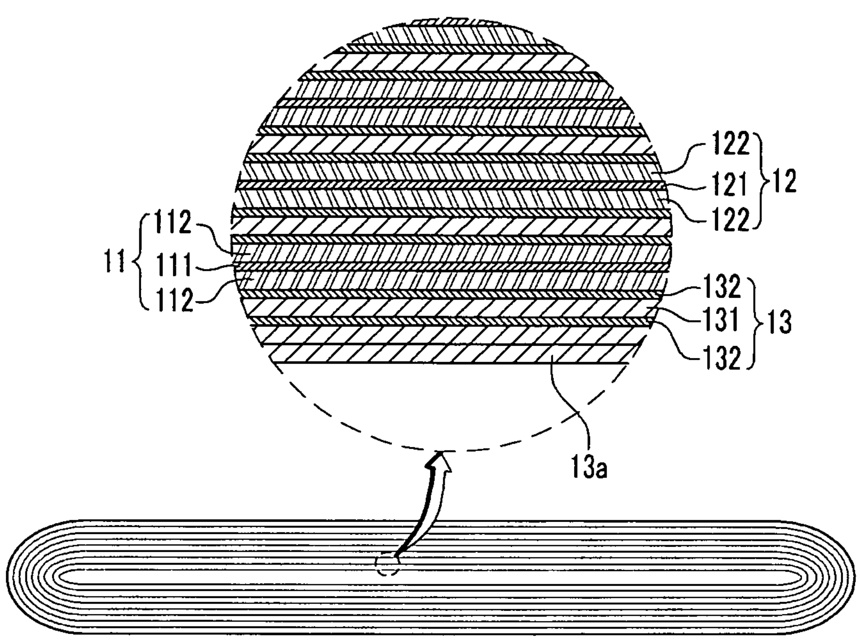


FIG. 5

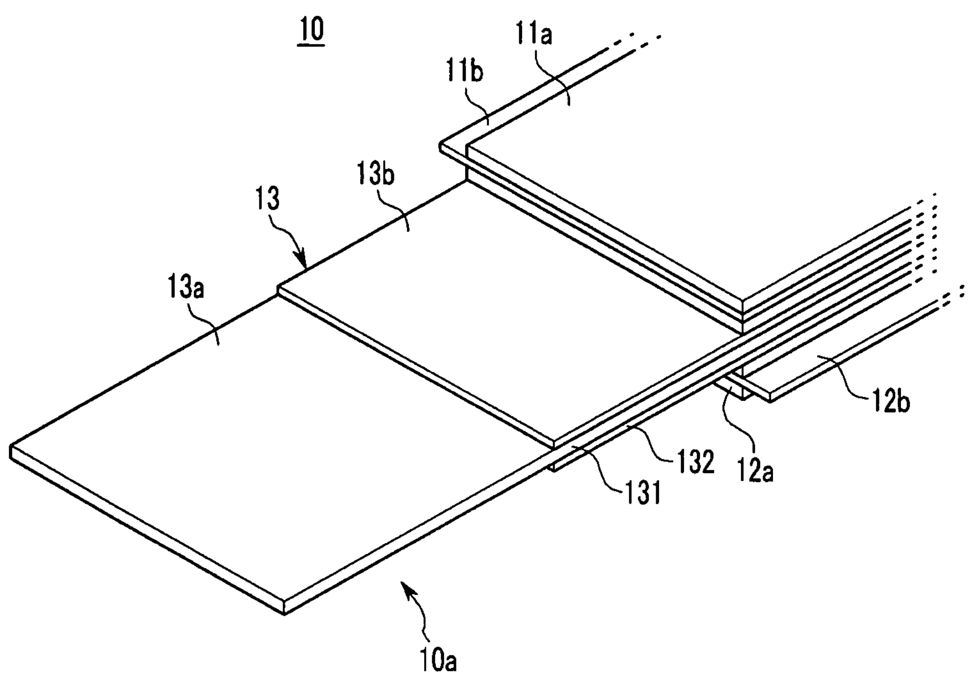


FIG. 6

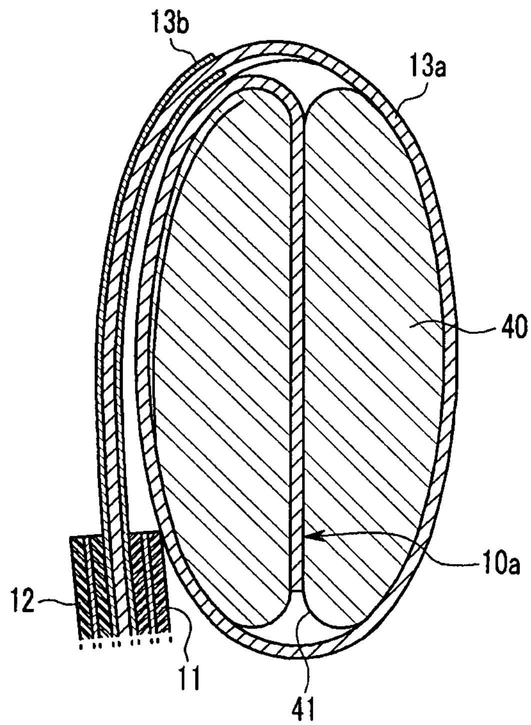


FIG. 7

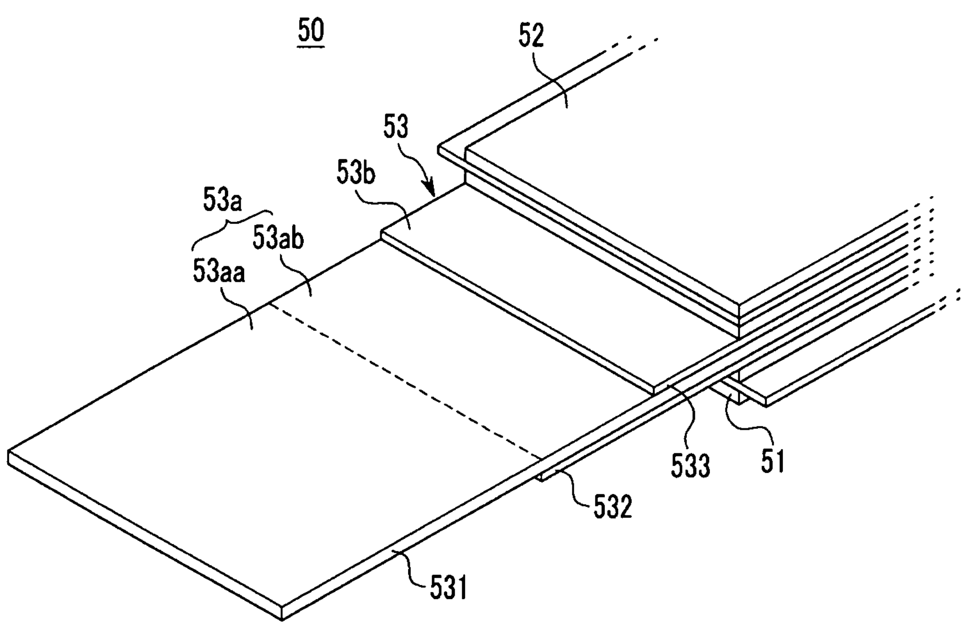


FIG. 8

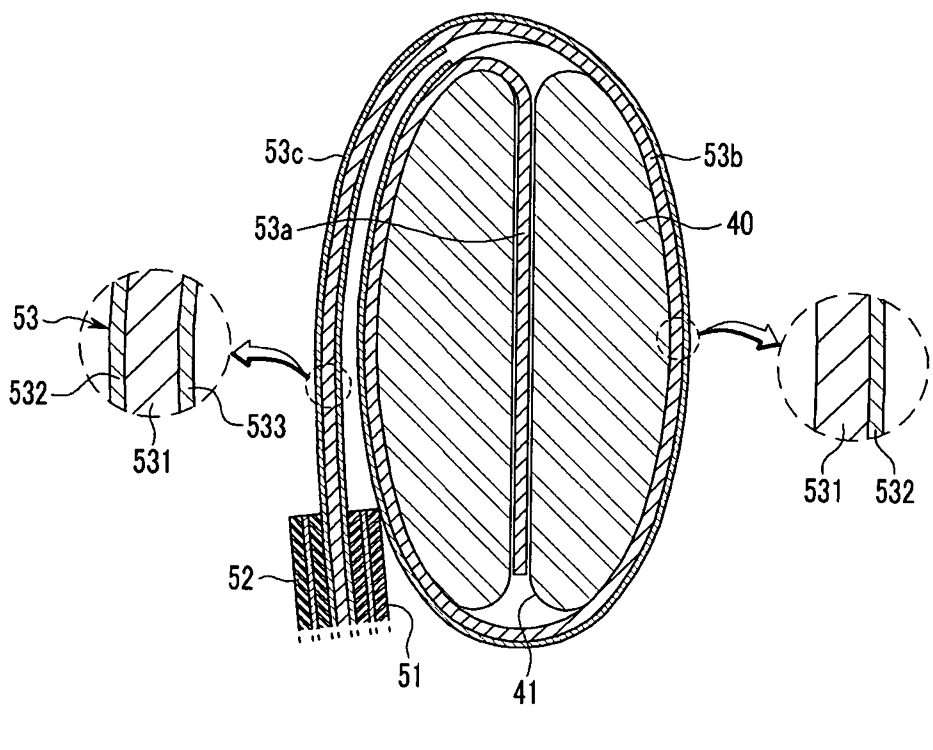


FIG. 9

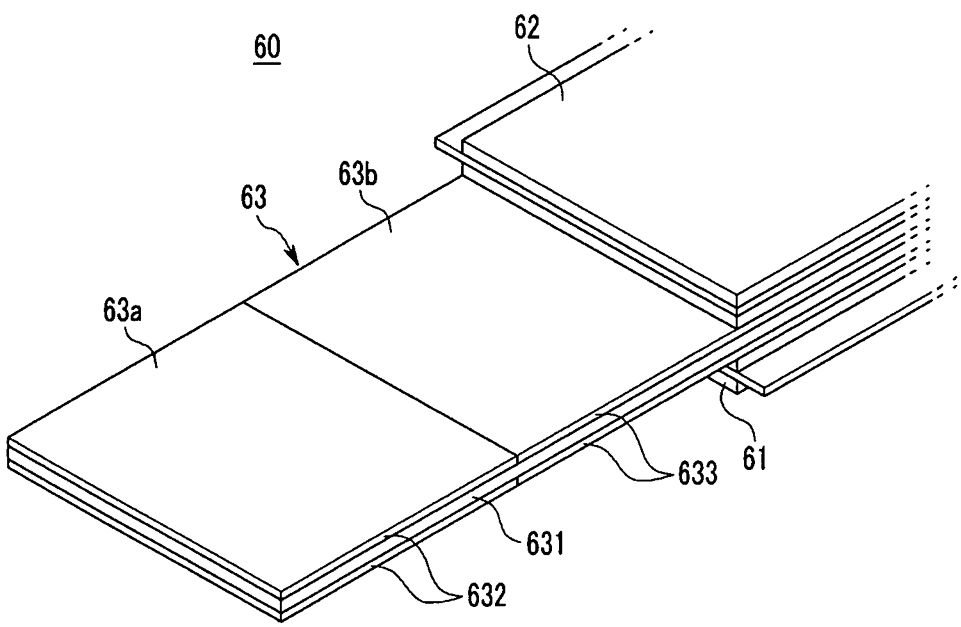
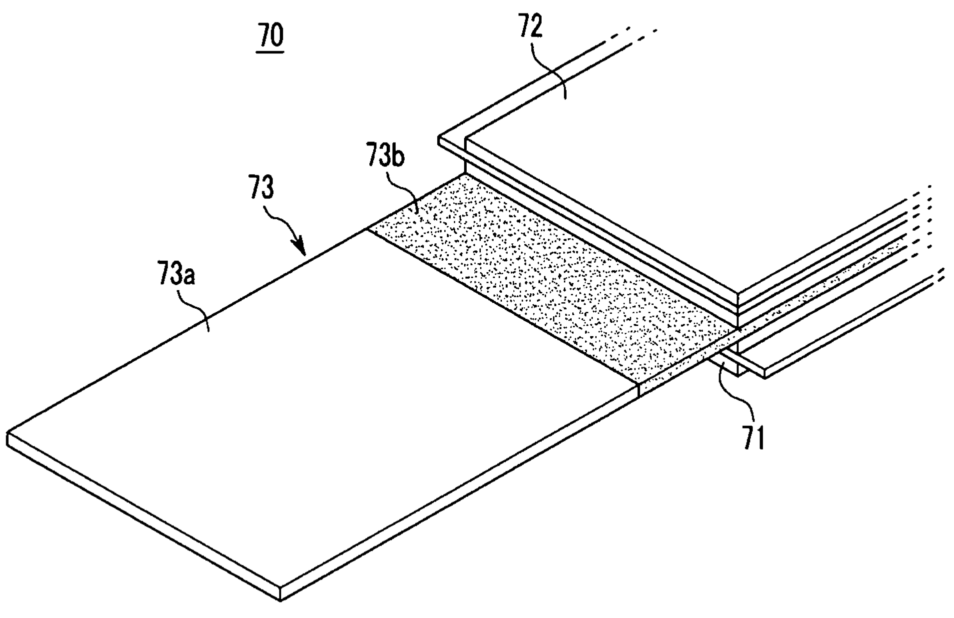


FIG. 10



ELECTRODE ASSEMBLY AND RECHARGEABLE BATTERY USING THE SAME

BACKGROUND

1. Field

The described technology relates generally to an electrode assembly for a rechargeable battery. More particularly, the described technology relates generally to an electrode assembly having an improved separator and a rechargeable battery using the same.

2. Description of the Related Art

Unlike a primary battery, a rechargeable battery can be charged and discharged. Low-capacity rechargeable batteries are used for portable compact electronic apparatuses, e.g., mobile phones, notebook computers, and camcorders, and high-capacity rechargeable batteries are widely used as a power source, e.g., for driving a motor of a hybrid vehicle, etc.

The rechargeable battery includes an electrode assembly and a case in which the electrode assembly is installed, and the case may have a cylindrical shape, a prismatic shape, a pouch shape, etc. The electrode assembly includes a positive electrode, a negative electrode, and a separator disposed between the positive and negative electrodes. Here, the separator separates the positive electrode and the negative electrode to prevent a short-circuit therebetween, and absorbs electrolyte required for a battery reaction to maintain high ion conductivity.

The above information disclosed in this Background section is only for enhancement of understanding of the background of the described technology and therefore it may contain information that does not form the prior art that is already known in this country to a person of ordinary skill in the art.

SUMMARY

Embodiments are directed to an electrode assembly and a rechargeable battery including the same, which substantially overcome one or more of the problems due to the limitations and disadvantages of the related art.

It is therefore a feature of an embodiment to provide an electrode assembly with a separator structure capable of being easily, spirally wound.

It is therefore another feature of an embodiment to provide an electrode assembly with a separator structure having an improved stability.

It is yet another feature of an embodiment to provide a rechargeable battery with an electrode assembly having one or more of the above features.

At least one of the above and other features and advantages may be realized by providing an electrode assembly, including a positive electrode including a positive electrode current collector and a positive electrode active material layer on the positive electrode current collector, a negative electrode including a negative electrode current collector and a negative electrode active material layer on the negative electrode current collector, and a separator between the positive and negative electrodes, the separator including a heat-resistive unit and a lubrication unit, the heat-resistive unit having a heat-resistive material, and the lubrication unit being at an inner front end of the spirally winding separator and having a friction coefficient that is lower than that of the heat-resistive unit.

The heat-resistive material may be an aramid. The heat-resistive material may include at least one ceramic, PVDF, and PVDF-HFP.

The separator may include a separator member and a first heat-resistive layer on a portion of the separator member, the first heat-resistive layer being in the heat-resistive unit, and the separator member including a polymeric porous membrane. The lubrication unit may include a portion of the separator member without the first heat-resistive layer. Further, the electrode assembly may include a lubrication layer in the lubrication unit, the lubrication layer having a friction coefficient that is lower than that of the separator member.

The separator may further include a second heat-resistive layer on a portion of the separator member, the first and second heat-resistive layers being on opposite surfaces of the separator member, and the lubrication unit may include a first lubrication unit and a second lubrication unit, the first lubrication unit including a portion of the separator member without the first or second heat-resistive layers, and he second lubrication unit including only one of the first and second heat-resistive layers. The heat-resistive material may be embedded in the heat-resistive unit, and a friction coefficient of the lubrication unit may be lower than that of the heat-resistive unit by about 0.1 to about 0.3.

At least one of the above and other features and advantages may also be realized by providing a rechargeable battery, including an spirally winding electrode assembly having a positive electrode, a negative electrode, and a separator between the positive and negative electrodes, a case in which the electrode assembly is installed, and a terminal electrically connected to the electrode assembly and externally protruding from the case, wherein the separator includes a heat-resistive unit and a lubrication unit, the heat-resistive unit having a heat-resistive material, and the lubrication unit being at an inner front end of the separator and having a friction coefficient that is lower than that of the heat-resistive unit.

The heat-resistive material may be an aramid. The heat-resistive material may include at least one of ceramic, PVDF, and PVDF-HFP.

The separator may include a separator member and a heat-resistive layer on a portion of the separator member, the heat-resistive layer being in the heat-resistive unit, and the separator member including a polymeric porous membrane. The lubrication unit may include a portion of the separator member without the first heat-resistive layer. A lubrication layer having a friction coefficient that is lower than that of the separator member may be formed in the lubrication unit.

The separator may include a separator member formed with a polymer porous membrane, a first heat-resistive layer formed at one side of the separator member, and a second heat-resistive layer formed at the other side of the separator member, The first and second heat-resistive layers may be formed in the heat-resistive unit, and the lubrication unit may include a first lubrication unit where the first and second heat-resistive layers are not formed and a second lubrication unit where a heat-resistive layer is formed only at one side of the separator member. A heat-resistive material may be embedded in the heat-resistive unit, and a friction coefficient of the lubrication unit may be lower than that of the heat-resistive unit by 0.1 to 0.3.

BRIEF DESCRIPTION OF THE DRAWINGS

The above and other features and advantages will become more apparent to those of ordinary skill in the art by describing in detail exemplary embodiments with reference to the attached drawings, in which:

FIG. 1 illustrates a perspective view of a rechargeable battery according to a first exemplary embodiment.

FIG. 2 illustrates a cross-sectional view of FIG. 1, taken along line II-II.

FIG. 3 illustrates a perspective view of an electrode assembly according to the first exemplary embodiment.

FIG. 4 illustrates a cross-sectional view of FIG. 3, taken along line IV-IV.

FIG. 5 illustrates a partial perspective view of the electrode assembly before it is wound according to the first exemplary embodiment.

FIG. 6 illustrates a cross-sectional view of the electrode assembly wound around a winder according to the first exemplary embodiment.

FIG. 7 illustrates a partial perspective view of an electrode assembly of a rechargeable battery according to a second exemplary embodiment.

FIG. 8 illustrates a cross-sectional view of an electrode assembly wound around a winder according to the second exemplary embodiment.

FIG. 9 illustrates a partial perspective view of an electrode assembly of a rechargeable battery according to a third exemplary embodiment.

FIG. 10 illustrates a partial perspective view of an electrode assembly of a rechargeable battery according to a fourth exemplary embodiment.

DETAILED DESCRIPTION

Korean Patent Application No. 10-2010-0030072, filed on Apr. 1, 2010, in the Korean Intellectual Property Office, and entitled: "Electrode Assembly and Rechargeable Battery Using the Same," is incorporated by reference herein in its entirety.

Example embodiments will now be described more fully hereinafter with reference to the accompanying drawings; however, they may be embodied in different forms and should not be construed as limited to the embodiments set forth herein. Rather, these embodiments are provided so that this disclosure will be thorough and complete, and will fully convey the scope of the invention to those skilled in the art.

In the drawing figures, the dimensions of layers and regions may be exaggerated for clarity of illustration. It will also be understood that when a layer (or element) is referred to as being "on" another layer or substrate, it can be directly on the other layer or substrate, or intervening layers may also be present. In addition, it will also be understood that when a layer is referred to as being "between" two layers, it can be the only layer between the two layers, or one or more intervening layers may also be present. Like reference numerals refer to like elements throughout.

FIG. 1 illustrates a perspective view of a rechargeable battery according to a first exemplary embodiment, and FIG. 2 illustrates a cross-sectional view of FIG. 1 along line II-II. Referring to FIG. 1 and FIG. 2, a rechargeable battery 100 may include an electrode assembly 10 performing charging and discharging, a case 34 in which the electrode assembly 10 is installed, and a cap assembly 20 connected to an opening of the case 34.

The rechargeable battery 100 according to the first exemplary embodiment is exemplarily described as a lithium ion battery. However, the example embodiments are not limited thereto and may be applied to various types of batteries, e.g., a lithium polymer battery.

The case 34 forms an entire external appearance of the rechargeable battery 100, and provides a space for installing the electrode assembly 10 therein. For example, the case 34 may be formed to have a cuboid shape with an opening at one side thereof for receiving a cubically-shaped electrode assembly 10. However, example embodiments are not limited thereto, e.g., the case 34 may be formed with a pouch shape. For example, the case 34 may be formed of metal, e.g., aluminum, an aluminum alloy, nickel-plated steel, and/or a pouched laminate film

The cap assembly 20 may include a plate-shaped cap plate 30. The cap plate 30 may be coupled to the opening formed in the case 34. A sealing cap 38 may be provided in an electrolyte solution injection hole 27 formed in the cap plate 30. In addition, a vent plate 39 with a notch 39*a* may be positioned in a vent hole provided in the cap plate 30, so the vent plate 39 may open or close under a predetermined pressure.

Positive and negative electrode terminals 21 and 22 may be electrically connected to the electrode assembly 10, and the positive and negative terminals 21 and 22 may protrude to the outside of the case 34. The positive and negative terminals 21 and 22 may pass through the cap plate 30. The positive and negative terminals 21 and 22 may have pillar shapes protruding through the cap plate 30 and may include respective terminal flanges supported at the bottom of the cap plate 30. Outer circumferences of the upper pillars protruding to the outside of the cap plate 30 may be screw-processed. In addition, nuts 29 may be coupled to the positive and negative electrode terminals 21 and 22 while supporting them from the top side.

Upper and lower gaskets 25 and 28 may be installed between the positive and negative electrode terminals 21 and 22 and the cap plate 30, so as to seal and insulate the electrode terminals 21 and 22 and the cap plate 30 from each other. Washers 24 for buffering a combining force may be formed on the upper gaskets 25. The positive electrode terminal 21 may be electrically connected to a positive electrode 11 via a first lead tab 31, and the negative terminal 22 may be electrically connected to a negative electrode 12 via a second lead tab 32.

A lower insulating member 26 may be disposed under the cap plate 30, and the bottom ends of the electrode terminals 21 and 22 and the top ends of the lead tabs 31 and 32 may be inserted into the lower insulating member 26. With this structure, the first lead tab 31 may electrically interconnect the positive electrode terminal 21 and the positive electrode 11, and the second lead tab 32 may electrically interconnect the negative electrode terminal 22 and the negative electrode 12.

FIG. 3 illustrates a perspective view of the electrode assembly 10 according to the first exemplary embodiment, and FIG. 4 illustrates a cross-sectional view of FIG. 3 along line IV-IV. Referring to FIG. 3 and FIG. 4, the positive electrode 11, the negative electrode 12, and a separator 13 may be band-shaped and elongated along one direction. The separator 13 may be disposed between the positive and negative electrodes 11 and 12, so the separator 13 with the positive and negative electrodes 11 and 12 may be wound together in a jelly-roll shape to form the electrode assembly 10. A front end 10*a* (FIG. 5) of the electrode assembly 10 is positioned as an innermost end of a wound electrode assembly 10, i.e., an end around which the remaining electrode assembly 10 is wound.

Referring to FIG. 4, the positive electrode 11 may have a structure in which positive electrode active material layers 112 are formed at both sides of a positive electrode current collector 111. In detail, the positive electrode current collector 111 may be formed in a long band shape, and may be made of metal, e.g., aluminum or stainless steel. The positive electrode active material layer 112 may be deposited on opposing surfaces of the positive electrode current collector 111, and may include a positive active material, e.g., $LiCoO_2$,

$LiMnO_2$, $LiFePO_4$, $LiNiO_2$, and $LiMn_2O_4$, a carbon-based active material, a trivalent active material, etc., and a conductive agent and a binder.

The negative electrode **12** may have a structure in which negative electrode active material layers **122** are formed at both sides of a negative electrode current collector **121**. In detail, the negative electrode current collector **121** may be formed in a long band shape, and may be made of a metal, e.g., copper, stainless steel, or aluminum. The negative electrode active material layer **122** may be deposited on opposing surfaces of the negative electrode current collector **121**, and may include a negative electrode active material, e.g., $Li_4Ti_5O_{12}$ or a carbon-based active material, a conductive agent, and a binder.

In further detail, the positive electrode **11** may include a positive electrode coated region **11***a* (FIG. **5**) in which the positive electrode active material layer **112** is formed and a positive electrode uncoated region **11***b* (FIGS. **3** and **5**) in which the positive electrode active material layer **112** is not formed. In other words, the positive electrode current collector **111** is exposed in the positive electrode uncoated region **11***b*. The positive electrode uncoated region **11***b* may be formed along a length direction of the positive electrode **11** at one side end of the electrode assembly **10**, as illustrated in FIGS. **3** and **5**.

Similarly, the negative electrode **12** may include a negative electrode coated region **12***a* (FIG. **5**) in which the negative electrode active material layer **122** is formed and a negative electrode uncoated region **12***b* (FIG. **5**) in which the negative electrode active material layer **122** is not formed. In other words, the negative electrode current collector **121** is exposed in the negative electrode uncoated region **12***b*.

As illustrated in FIGS. **4** and **5**, the separator **13** may include a separator member **131** and a heat-resistive layer **132** formed on at least one surface of the separator member **131**, e.g., two heat-resistive layers **132** may be formed on respective opposite surfaces of the separator member **131**. For example, the heat-resistive layer **132** may be formed only on a first portion of the surface of the separator member **131**, i.e., a portion of the separator **13** may include the separator **131** without the heat resistive layer **132** thereon. In detail, as illustrated in FIG. **5**, the separator **13** may include a heat-resistive unit **13***b* and a lubrication unit **13***a* adjacent to the heat-resistive unit **13***b*. The heat-resistive unit **13***b* refers to a region of the separator **13** that includes the heat-resistive layer **132** on the separator member **131**, and the lubrication unit **13***a* refers to a region of the separator **13** including only the separator member **131**, i.e., without the heat resistive layer **132**. The lubrication unit **13***a* may have a friction coefficient that is lower than that of the heat-resistive unit **13***b*, i.e., a friction coefficient of the separator member **131** may be lower than that of the heat-resistive layer **132**.

The separator member **131** may include a polymeric porous membrane, and may be made of various materials applied to the separator **13**. The heat-resistive layer **132** may be formed of a heat-resistant material, e.g., aramid. The aramid is highly resistive to heat and has excellent ion conductivity and, therefore, may guarantee heat resistance of the separator **13** without deteriorating performance of the separator **13**, e.g., as compared to other heat-resistant materials. However, the exemplary embodiment are not limited thereto, and the heat-resistive layer **132** may be made of various materials to be described hereinafter.

The heat-resistive layer **132** may be coated on the separator member **131**, and may prevent melting of the separator **13** when the internal temperature of the rechargeable battery **100** is increased. In contrast, when a conventional separator is formed to include only a separator member, e.g., a polymeric porous membrane without a heat-resistive layer thereon, the separator member may melt or contract at a high temperature, e.g., due to overcharge, thereby causing a short circuit between the positive electrode active material layer **112** and the negative electrode active material layer **122** (or between the negative electrode active material layer **122** and the positive electrode current collector **111**). When the short circuit occurs between the positive and negative electrodes, a large amount of heat may be generated in the rechargeable battery so that the rechargeable battery may combust or explode. However, the heat-resistive layer **132** on the separator member **131**, according to exemplary embodiments, prevents melting of the separator member **131**, thereby preventing a short circuit between the positive and negative electrodes **11** and **12**.

As described previously, the heat-resistive layer **132** may be formed only on the first portion of the separator member **131**. That is, as illustrated in FIG. **5**, an edge of the separator **13**, i.e., the lubrication unit **13***a*, may not include the heat-resistive layer **132**. Further, the lubrication unit **13***a* of the separator **13** may be formed at the front end **10***a* of an unwound electrode assembly **10** to directly contact a winder **40** (FIG. **6**) to wound the separator **13** with the positive and negative electrodes **11** and **12** into a wound electrode assembly **10** illustrated in FIG. **3**. Attachment of the lubrication unit **13***a*, i.e. a portion of the separator **13** without the heat-resistive layer **132**, to the winder **40** improves separation of the electrode assembly **10** from the winder **40** after the electrode assembly **10** is spirally wound, e.g., a direct contact between the heat-resistive layer **132** and the winder **40** may make the separation of the electrode assembly **10** from the winder **40** difficult due to the high friction coefficient of the heat-resistive layer **132**.

In detail, as illustrated in FIG. **6**, the winder **40** may have an overall cross-section with a groove **41** at a center thereof, and the electrode assembly **10** may be wound on the external circumferential surface of the winder **40**. For example, only the separator **13**, i.e., the lubrication unit **13***a*, may be inserted into the groove **41** and wound on the external circumferential surface of the winder **40**. After the separator **13** is partially wound on the winder **40**, e.g., the lubrication unit **13***a* forms one complete circle around the circumference of the winder **40**, the heat-resistive unit **13***b* of the separator, the positive electrode **11**, and the negative electrode **12** may be wound on the lubrication unit **13***a* around the winder **40**.

The portion where only the separator **13** is contacting the winder **40** prevents the active material on the electrodes from staining the winder **40**. Simultaneously, a direct contact of the lubrication unit **13***a* of the separator **13** with the winder **40** facilitates separation of the electrode assembly **10** from the winder **40**.

For this reason, as illustrated in FIG. **5**, the portion where only the separator **13** is located exists at the inner front end **10***a* of the electrode assembly **10**. Since the lubrication unit **13***a* exists at the portion where only the separator **13** is wound, the lubrication unit **13***a* and the winder **40** contact each other when being spirally wound. In the lubrication unit **13***a*, the heat-resistive layer **132** is not formed and the separator member **131** is exposed. The separator member **131** has a friction coefficient that is lower than that of the heat-resistive layer **132**, and therefore the lubrication unit **13***a* may be separated from the winder **40** with ease. For example, the lubrication unit **13***a* may have a friction coefficient of about 0.3 to about 0.4, and the heat-resistive layer **132** may have a friction coefficient of about 0.5 to about 0.6. For example, the friction coefficient of the lubrication unit **13***a* may be lower than that of the heat-resistive layer **132** by about 0.1 to about 0.3 in the present exemplary embodiment.

As discussed previously, if a heat-resistive unit having a friction coefficient that is higher than that of a lubrication unit contacts the winder **40**, the front end of the separator, i.e., the heat-resistive unit, cannot be easily separated from the winder **40**, e.g., the separator may be stuck to the winder, and an internal portion of the electrode assembly **10** may protrude when the electrode assembly **10** is separated from the winder **40**. As such, the electrode assembly **10** may deform and necessitate manual correction of the shape of the electrode assembly **10**, thereby substantially reducing productivity. This problem occurs because the front end of the electrode assembly **10** cannot be easily slid in the winder **40**.

However, in the present exemplary embodiment, the lubrication unit **13***a*, i.e., where the heat-resistive layer **132** is not formed, may be positioned at the front end **10***a* of the electrode assembly **10** that contacts the winder **40**. As the lubrication unit **13***a* is easily separated from the winder **40**, deformation of the electrode assembly **10** may be prevented. In addition, the heat-resistive unit **13***b* may be formed at a portion that is adjacent to the lubrication unit **13***a*, e.g., the heat-resistive unit **13***b* and lubrication unit **13***a* may be in direct contact with each other, and the positive electrode **11** and the negative electrode **12** may be arranged to have the heat-resistive unit **13***b* therebetween. Therefore, a short circuit of the positive electrode **11** and the negative electrode **12** may be prevented when the internal temperature of the rechargeable battery **100** is increased.

FIG. **7** illustrates a partial perspective view of an unwound electrode assembly of a rechargeable battery according to a second exemplary embodiment. FIG. **8** illustrates a cross-sectional view of the electrode assembly of FIG. **7** wound around a winder.

Referring to FIG. **7** and FIG. **8**, an electrode assembly **50** according to the present exemplary embodiment may include a positive electrode **51**, a negative electrode **52**, and a separator **53** disposed between the positive and negative electrodes **51** and **52**. The rechargeable battery of the present exemplary embodiment is the same as that of the first exemplary embodiment, with the exception of the structure of the separator **53**. Therefore, a detailed description of the same elements will not be repeated.

Referring to FIG. **7**, the separator **53** according to the present exemplary embodiment may include a heat-resistive unit **53***b* having a first heat-resistive layer **532** and a second heat-resistive layer **533** respectively formed on both sides of a separator member **531**. Further, the separator **53** may include a lubrication unit **53***a* having a friction coefficient that is lower than that of the heat-resistive unit **53***b*. It is noted that the friction coefficient of the heat-resistive unit **53***b* refers to an average value of friction coefficients of both sides of the separator **53**, i.e., of the first and second heat-resistive layers **532** and **533**. The first heat-resistive layer **532** and the second heat-resistive layer **533** may be made of, e.g., ceramic, polyvinylidene fluoride (PVDF), or PVDF-HFP.

The lubrication unit **53***a* may include a first lubrication unit **53***aa* and a second lubrication unit **53***ab* adjacent to the first lubrication unit **53***aa*. The first lubrication unit **53***aa* refers to a region of the separator **53** where both sides of the separator member **531** are exposed. The second lubrication unit **53***ab* refers to a region of the separator **53** where only one side, i.e., surface, of the separator member **531** is exposed, i.e., the second lubrication unit **53***ab* is formed only on one surface of the separator member **531**. The first heat-resistive layer **532** may extend on a surface of the separator member **531** that is opposite the second lubrication unit **53***ab*. Further, the first heat-resistive layer **532** may overlap the second lubrication unit **53***ab*. Therefore, the second lubrication unit **53***ab* may have a friction coefficient that is lower than that of the heat-resistive unit **53***b* and higher than that of the first lubrication unit **53***aa*.

A illustrated in FIG. **8**, the first lubrication unit **53***aa* may be inserted into the groove **41** formed in the winder **40**, such that both sides thereof contact the winder **40**, and one side of the second lubrication unit **53***ab* contacts the external surface of the winder **40**. As described, according to the present exemplary embodiment, the heat-resistive layers **532** and **533** may not be formed in the portion of the separator **53** contacting the winder **40**. Thus, the electrode assembly **10** may be easily separated from the winder **40** after spiral-winding is finished. In addition, the second heat-resistive layer **533** may be formed at one side of the second lubrication unit **53***ab*, so that the strength of the second lubrication unit **53***ab* may be improved. Accordingly, deformation of the second lubrication unit **53***ab* may be prevented.

FIG. **9** illustrates a partial perspective view of an unwound electrode assembly of a rechargeable battery according to a third exemplary embodiment. Referring to FIG. **9**, an electrode assembly **60** according to the present exemplary embodiment may include a positive electrode **61**, a negative electrode **62**, and a separator **63** disposed between the positive and negative electrodes **61** and **62**. The rechargeable battery according to the present exemplary embodiment is the same as that of the first exemplary embodiment, with the exception of the structure of the separator **63**. Therefore, detailed descriptions of the same elements will not be repeated.

The separator **63** according to the present exemplary embodiment may include a heat-resistive unit **63***b* having a heat-resistive layer **633** formed at both sides of a separator member **631**, and a lubrication unit **63***a* having a friction coefficient that is lower than that of the heat-resistive unit **63***b*. The heat-resistive layer **633** may be coated over both sides of the separator member **631** in the heat-resistive unit **63***b*. The heat-resistive layer **633** may be made of, e.g., an aramid, ceramic, PVDF, PVDF-HFP, etc.

In the lubrication unit **63***a*, a lubrication layer **632** may be coated over both sides of the separator member **631**. The lubrication layer **632** may include a material having a friction coefficient that is lower than that of the separator member **631**. The lubrication layer **632** may be made of a solid, e.g., a polymer material, and may have a structure in which a liquid, e.g., a lubrication solution that does not react with an electrolyte solution, may be coated thereon. The lubrication layer **632** may be located at the front end of the electrode assembly **60**. Thus, the lubrication layer **632** may contact the winder when being spirally wound. In this case, the lubrication layer **632** may have a friction coefficient of about 0.1 to about 0.3 for separation from the winder with ease. In the present exemplary embodiment, the spirally-wound electrode assembly **60** may be easily separated from the winder by forming the lubrication layer **632** having a friction coefficient that is lower than that of the separator **631**.

FIG. **10** illustrates a partial perspective view of an electrode assembly of a rechargeable battery according to a fourth exemplary embodiment. Referring to FIG. **10**, an electrode assembly **70** according to the present exemplary embodiment may include a positive electrode **71**, a negative electrode **72**, and a separator **73** disposed between the positive and negative electrodes **71** and **72**. The rechargeable battery of the present exemplary embodiment is the same as that of the first exemplary embodiment, with the exception of the structure of the separator **73**, and therefore, detailed descriptions of the same elements will not be repeated.

The separator **73** according to the present exemplary embodiment may include a heat-resistive unit **73***b* where a heat-resistive material is embedded in a separator member, and a lubrication unit **73***a* having a friction coefficient that is lower than that of the heat-resistive unit **73***b*. A material embedded in the heat-resistive unit **73***b*, e.g., a ceramic material, may be more heat-resistive than the separator member. When the heat-resistive material is embedded in the separator member, heat-resistivity of the separator **73** is increased. Thus, the separator **73** may be prevented from being melted at a high temperature, thereby improving stability of the rechargeable battery.

The heat-resistive material is not embedded in the separator member located in the lubrication unit **73***a*. Accordingly, a friction coefficient of the lubrication unit **73***a* may be lower than that of the heat-resistive unit **73***b*. Since the positive electrode **71** and the negative electrode **72** are not stacked in the lubrication unit **73***a*, the positive electrode **71** and the negative electrode **72** may not be short-circuited when the lubrication unit **73***a* is melted at a high temperature. Accordingly, stability may not be deteriorated. In addition, only a lubrication unit may be located at the front end of the separator **73** to contact the winder when being spirally wound. Accordingly, the electrode assembly **70** may be easily separated from the winder after the spiral-winding.

According to the exemplary embodiments, a separator of an electrode assembly may include a heat-resistive unit that prevent melting of the separator at high temperatures. Accordingly, an internal short-circuit between the electrodes of the electrode assembly may be prevented, thereby improving stability. In addition, the separator of the electrode assembly may include a lubrication unit that may easily separate the electrode assembly from a winder, thereby improving productivity.

<Description of symbols>

100: rechargeable battery	10, 50, 60, 70: electrode assembly
11, 51, 61, 71: positive electrode	
111: positive electrode current collector	
112: positive electrode active material layer	
11a: positive electrode coated region	
11b: positive electrode uncoated region	
12, 52, 62, 72: negative electrode	
121: negative electrode current collector	
122: negative electrode active material layer	
12a: negative electrode coated region	
12b: negative electrode uncoated region	
13, 53, 63, 73: separator	131, 531, 631: separator member
132, 633: heat-resistive layer	13a, 53a, 63a, 73a: lubrication unit
13b, 53b, 63b, 73b: heat-resistive unit	
20: cap assembly	22: negative terminal
24: washer	25: upper gasket
26: insulating member	27: electrolyte solution injection hole
28: lower gasket	
29: nut	30: cap plate
31: first lead tab	32: second lead tab
34: case	38: sealing cap
39: vent plate	39a: notch
40: winder	41: groove
532: first heat-resistive layer	533: second heat-resistive layer
53aa: first lubrication unit	53ab: second lubrication unit
632: lubrication layer	

Exemplary embodiments have been disclosed herein, and although specific terms are employed, they are used and are to be interpreted in a generic and descriptive sense only and not for purpose of limitation. Accordingly, it will be understood by those of ordinary skill in the art that various changes in form and details may be made without departing from the spirit and scope of the present invention as set forth in the following claims.

What is claimed is:

1. An electrode assembly, comprising:

a positive electrode including a positive electrode current collector and a positive electrode active material layer on the positive electrode current collector;

a negative electrode including a negative electrode current collector and a negative electrode active material layer on the negative electrode current collector; and

a separator between the positive and negative electrodes, the separator including a heat-resistive unit and a lubrication unit, the heat-resistive unit having a heat-resistive material, and the lubrication unit having a friction coefficient that is lower than that of the heat-resistive unit,

wherein the lubrication unit is at an inner front end of the separator, the lubrication unit extending beyond an inner front end of each of the positive and negative electrodes, the inner front ends of the separator, positive electrode, and negative electrodes facing a same direction, and

wherein a portion of the heat-resistive unit of the separator extends beyond the inner front end of each of the positive and negative electrodes along a winding direction of the electrode assembly, the lubrication unit extending beyond an edge of the heat-resistive unit along the winding direction of the electrode assembly.

2. The electrode assembly as claimed in claim **1**, wherein the heat-resistive material is an aramid.

3. The electrode assembly as claimed in claim **1**, wherein the heat-resistive material includes at least one of ceramic, PVDF, and PVDF-HFP.

4. The electrode assembly as claimed in claim **1**, wherein the separator includes a separator member and a first heat-resistive layer on a portion of the separator member, the first heat-resistive layer being in the heat-resistive unit, and the separator member including a polymeric porous membrane.

5. The electrode assembly as claimed in claim **4**, wherein the lubrication unit includes a portion of the separator member without the first heat-resistive layer.

6. The electrode assembly as claimed in claim **5**, further comprising a lubrication layer in the lubrication unit, the lubrication layer having a friction coefficient that is lower than that of the separator member.

7. The electrode assembly as claimed in claim **4**, wherein:

the separator further comprises a second heat-resistive layer on a portion of the separator member, the first and second heat-resistive layers being on opposite surfaces of the separator member; and

the lubrication unit includes a first lubrication unit and a second lubrication unit, the first lubrication unit including a portion of the separator member without the first or second heat-resistive layers, and the second lubrication unit including only one of the first and second heat-resistive layers.

8. The electrode assembly as claimed in claim **1**, wherein the heat-resistive material is embedded in the heat-resistive unit.

9. The electrode assembly as claimed in claim **1**, wherein a friction coefficient of the lubrication unit is lower than that of the heat-resistive unit by about 0.1 to about 0.3.

10. A rechargeable battery, comprising:

an spirally winding electrode assembly having a positive electrode, a negative electrode, and a separator between the positive and negative electrodes;

a case in which the electrode assembly is installed; and

a terminal electrically connected to the electrode assembly and externally protruding from the case,

wherein the separator includes a heat-resistive unit and a lubrication unit, the heat-resistive unit having a heat-resistive material, and the lubrication unit being at an inner front end of the separator and having a friction coefficient that is lower than that of the heat-resistive unit,

wherein the positive electrode includes a positive electrode current collector and a positive electrode active material layer on the positive electrode current collector, and the negative electrode includes a negative electrode current collector and a negative electrode active material layer on the negative electrode current collector,

wherein the lubrication unit is at an inner front end of the separator, the lubrication unit extending beyond an inner front end of each of the positive and negative electrodes, the inner front ends of the separator, positive electrode, and negative electrodes facing a same direction, and

wherein a portion of the heat-resistive unit of the separator extends beyond the inner front end of each of the positive and negative electrodes along a winding direction of the electrode assembly, the lubrication unit extending beyond an edge of the heat-resistive unit along the winding direction of the electrode assembly.

11. The rechargeable battery as claimed in claim **10**, wherein the heat-resistive material is an aramid.

12. The rechargeable battery as claimed in claim **10**, wherein the heat-resistive material includes at least one of ceramic, PVDF, and PVDF-HFP.

13. The rechargeable battery as claimed in claim **10**, wherein the separator includes a separator member and a first heat-resistive layer on a portion of the separator member, the first heat-resistive layer being in the heat-resistive unit, and the separator member including a polymeric porous membrane.

14. The rechargeable battery as claimed in claim **13**, wherein the lubrication unit includes a portion of the separator member without the first heat-resistive layer.

15. The rechargeable battery as claimed in claim **14**, further comprising a lubrication layer in the lubrication unit, the lubrication layer having a friction coefficient that is lower than that of the separator member.

16. The rechargeable battery as claimed in claim **13**, wherein:

the separator further comprises a second heat-resistive layer on a portion of the separator member, the first and second heat-resistive layers being on opposite surfaces of the separator member; and

the lubrication unit includes a first lubrication unit and a second lubrication unit, the first lubrication unit including a portion of the separator member without the first or second heat-resistive layers, and the second lubrication unit including only one of the first and second heat-resistive layers.

17. The rechargeable battery as claimed in claim **10**, wherein the heat-resistive material is embedded in the heat-resistive unit.

18. The rechargeable battery as claimed in claim **10**, wherein a friction coefficient of the lubrication unit is lower than that of the heat-resistive unit by about 0.1 to about 0.3.

19. The electrode assembly as claimed in claim **1**, wherein uncoated portions of the positive and negative electrodes extend in directions other than that of the inner front ends of the positive and negative electrodes.

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